Chapter 8

Central Place Foraging and Prehistoric Pinyon Utilization in the Great Basin

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INTRODUCTION

Great Basin archaeologists eagerly incorporated Binford's (1980) forager–collector model into their settlement pattern analyses because Julian Steward's (1933, 1938, 1941) work on the cultural ecology of Great Basin hunter-gatherers predisposed them to think of the influence of resource distributions on foraging and mobility strategies (Rhode 1999; Zeanah and Simms 1999).[1] Thomas' epistemologies for Monitor Valley and the Carson Desert of Nevada (Thomas 1983a, 1985) stood out as exemplary applications of the model (Bettinger 1991a: 70–73) because they demonstrated that ethnographic Great Basin bands that shared the same culture, language, and technology ran the gamut from pure foragers (i.e., Kawich Mountain Shoshone), through seasonally mixed foragers and collectors (i.e., Reese River Valley Shoshone and Carson Desert Paiute) to full-time

[1]Steward's contribution to the forager–collector model has been discussed elsewhere (Rhode 1999; Thomas 1983).

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collectors (i.e., Owens Valley Paiute). The dilemma posed by Thomas was that although the forager–collector model captures adaptive diversity among Great Basin hunter-gatherers, it fails to explain why such variability occurred in a region that lacked the global-scale differences in effective temperature posed by Binford as driving the forager–collector continuum. Almost 20 years ago, Thomas noted that "we currently lack the theoretical models to explain this variability" (1983a: 39), although he was optimistic that archaeological field research dedicated to development and application of "mid-range" models would eventually yield a theoretical understanding of variability among Great Basin settlement systems.

Substantial headway has been made in formulating the theoretical models that Thomas found lacking in 1983, but the progress results from a research tack different from that he anticipated (Zeanah and Simms 1999). Theoretically inspired by behavioral ecology, explorations of the cost–benefits of foraging in the Great Basin have, piece by piece, simplified the forager–collector model into constituent economic choices (i.e., which resources to harvest, which resources to transport, when to field process resources, and where to live). The contribution of field research has been to identify spatial and temporal variability in hunter-gatherer behavior not anticipated in Thomas' application of the forager–collector model to ethnographic cases. Archaeological research into prehistoric Great Basin pinyon (*Pinus monophylla*) procurement strategies illustrates this case.

GREAT BASIN PINYON PROCUREMENT STRATEGIES

Steward (1938: 27–28, 232) emphasized the importance of pinyon seeds as a storable food, whose productivity determined the size, permanence, and dispersion of winter villages among many ethnographic Great Basin groups. For this reason, a primary research goal of many subsistence-settlement studies was to assess the antiquity of pinyon procurement in the Great Basin (Bettinger 1976, 1977; Thomas 1973; Thomas and Bettinger 1976; Wells 1983). Site distributions discerned from probabilistic sample surveys of biotically defined strata (see Binford 1964), were analyzed under the assumption that statistically significant associations of camp assemblages (ground stone tools, rock-ring dwellings, and storage features) with pinyon-juniper woodlands reflect pinyon usage. The antiquity of pinyon procurement strategies was inferred from temporally diagnostic artifacts, radiocarbon dates, and obsidian hydration readings associated with pinyon camps.

Findings of these studies revealed that pinyon procurement strategies were geographically and temporally variable across the Great Basin (Fig. 8.1). For example, pinyon camps appeared in the forests above Reese

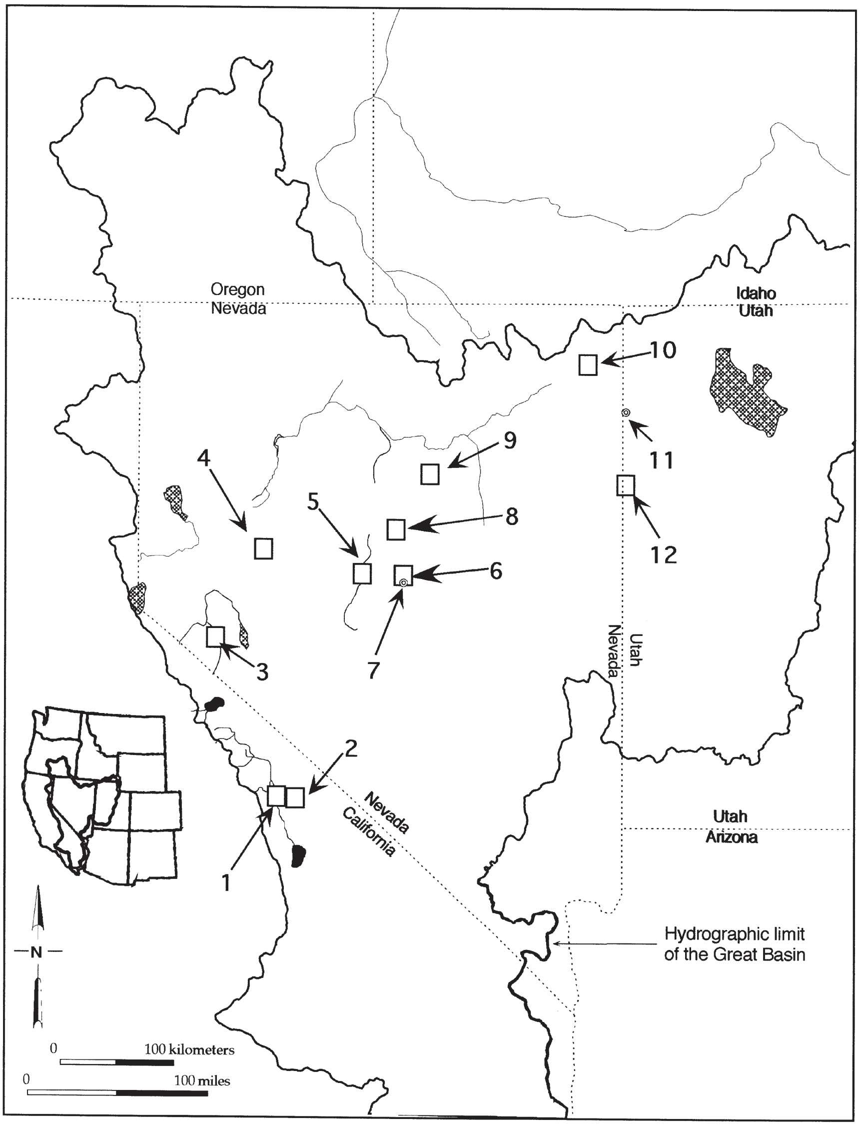

Figure 8.1. Map of Great Basin showing locations of pinyon-juniper surveys and sites mentioned in text. Key to locations:1. Owens Valley Survey (Bettinger 1976, 1977); 2. Deep Springs Valley Survey (Delacorte 1990); 3. Walker Lake Uplands Survey (Rhode 1990a); 4. Stillwater Survey (Kelly 2001); 5. Reese River Valley Survey (Thomas 1973; Thomas and Bettinger 1976); 6. Monitor Valley Survey (Thomas 1988); 7. Gatecliff Shelter (Thomas 1983b); 8. Grass Valley Survey (Wells 1983); 9. Cortez Survey (Delacorte et al. 1992); 10. Toano Draw Survey (Zeanah 1992); 11. Danger Cave (Rhode and Madsen 1998); 12. Deep Creek Survey (Lindsay and Sargent 1979).

River Valley as early as 6000 B.P., implying that the use of pinyon extends back to the Middle Holocene (Thomas 1973; Thomas and Bettinger 1976; Grayson 1993: 257). In contrast, woodlands of Owens Valley remained sparsely occupied until about 1350 B.P., indicating that hunter-gatherers bypassed pinyon as a food resource until that time (Bettinger 1977; Delacorte 1990). The results of these two surveys have different implications for interpreting Great Basin prehistory; the Reese River Valley survey suggests that the ethnographic pattern of pinyon procurement operated throughout the Holocene, whereas the Owens Valley survey indicates considerable variability in the role of pinyon over time. Subsequent surveys of pinyon-juniper woodlands elsewhere in the Great Basin failed to identify any pinyon camps whatsoever comparable to those of the Reese and Owens River Valleys (Delacorte et al. 1992; Kelly 2001; Lindsay and Sargent 1979; Zeanah 1992).

Inferences about the antiquity of pinyon procurement drawn from survey data were criticized because they lacked direct evidence in the form of macrofossils retrieved from dated contexts that pinyon was exploited as a dietary item from camps in pinyon zones. This was troubling because pinyon achieved its modern distribution only in the last few millennia (Madsen 1986; Grayson 1993), leaving open the possibility that associations of "pinyon camps" with pinyon-juniper woodlands were fortuitous and unrelated to pinyon procurement (Madsen 1981; see also Thomas 1981; Bettinger 1981; Delacorte et al. 1992).

In response to these criticisms, more concerted efforts to recover pinyon macrofossils from excavated contexts bolstered inferences drawn from site distributions (Bettinger 1989; Rhode 1980; Rhode and Thomas 1983; Wells 1983). In addition, paleoenvironmental research has emphasized tracing the Holocene expansion of pinyon so that its availability could be compared with local archaeological records. Many investigators expected that the development of economically exploitable pinyon groves in the central and northern Great Basin intensified occupation of those regions (Thomas 1982; Simms 1985; Grayson 1993). If so, variability in pinyon-juniper settlement patterns simply reflects local differences in the time that pinyon achieved its modern distribution.

Paleoenvironmental studies have revealed that the Holocene spread of pinyon through the Great Basin was a more complex process than the simple northward expansion initially expected (Lanner 1983; Madsen 1986). For example (Fig. 8.2), pinyon pine arrived in the vicinity of Danger Cave as early as 6700 B.P. (Rhode and Madsen 1998) but may not have appeared in the Stillwater Range until after 1250 B.P. (Kelly 2001: 36; Wigand and Nowak 1992). Nevertheless, this unanticipated complexity does not correlate

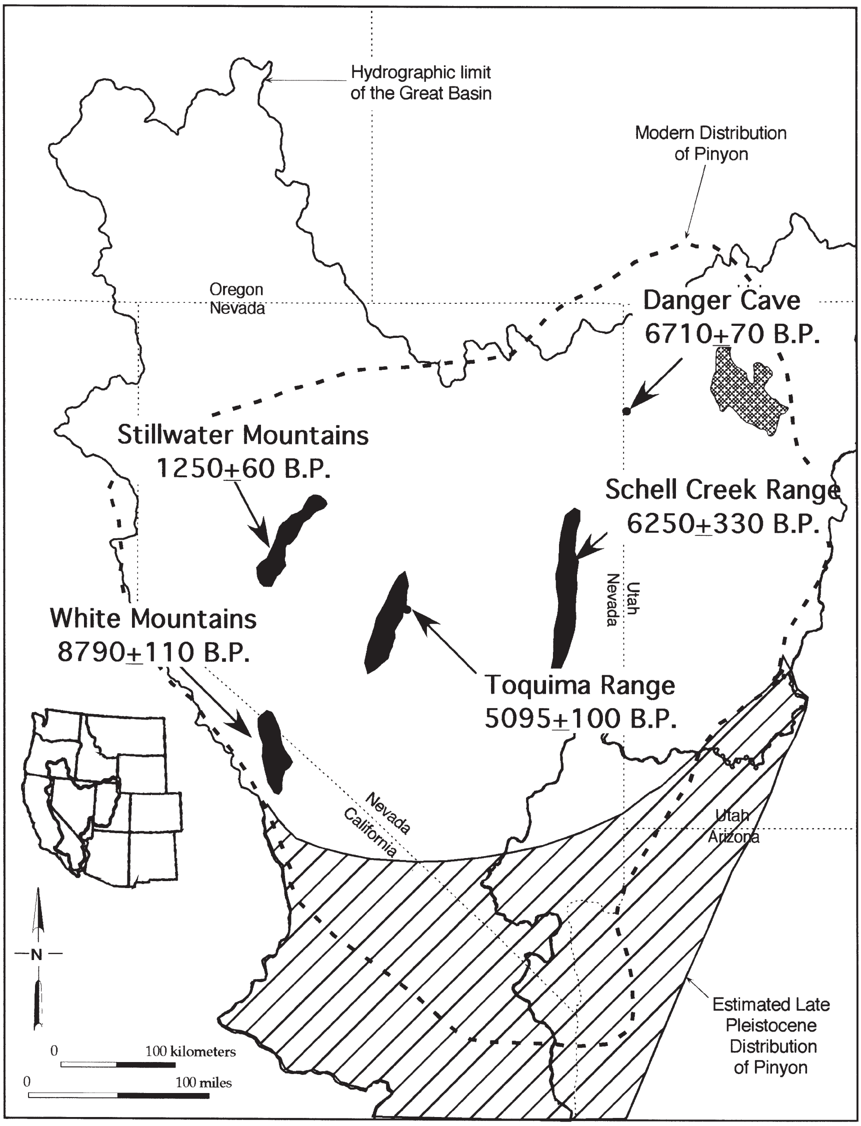

Figure 8.2. Map of Great Basin showing the modern distribution of pinyon (West et al. 1998), estimated Late Pleistocene distribution of pinyon (Madsen 1986), and radiocarbon dates from packrat middens and archaeological sites documenting the Holocene spread of pinyon (Jennings and Elliot-Fisk 1993; Rhode and Madsen 1998; Thompson and Hattori 1983; Wigand and Nowak 1992).

with variability among archaeological pinyon-juniper settlement patterns. Pinyon arrived in the Toquima Range about 6000 B.P. about when occupation of Gatecliff Shelter began (Thompson and Hattori 1983) and roughly contemporaneous with the inception of pinyon camp occupation in nearby Reese River and Grass Valleys (Thomas 1973, 1982; Wells 1983). In contrast, pinyon was present in the White Mountains by 8800 B.P. (Jennings and Elliot-Fisk 1993), many millennia before the association of sites with the pinyon woodlands of adjacent Owens and Deep Creek Valleys (Bettinger 1977; Delacorte 1990).

Another criticism of assessments of the antiquity of pinyon procurement derived from settlement pattern analyses concerned the effects of the mobility strategy employed for pinyon procurement on pinyon-juniper settlement patterns. McGuire and Garfinkel (1976) suggested that the 1350 B.P. appearance of pinyon camps in Owens Valley represented a local intensification of previously existing pinyon collection strategies, not the incorporation of a previously bypassed resource into hunter-gatherer diets. This inference was derived from inventory (although not a probabilistic sample survey) and test excavation of pinyon camps along the Pacific Crest Trail of the southern Sierra Nevada, south of Owens Valley (Garfinkel et al. 1980; McGuire and Garfinkel 1980). Drawing on pinyon collection strategies of the ethnographic Tubatulabal and Kawaisu Paiute as analogies, Garfinkel and McGuire proposed that pinyon camp assemblages could be categorized as either pinyon bases or temporary camps, suggesting that the 1350 B.P. appearance of pinyon camps in northern Owens Valley represented a shift from logistic to residential usage of pinyon woodlands. Rhode (1980) developed expectations for the deposition of pinyon macrofossils designed to distinguish the two types of pinyon camps. Pinyon should have been fully processed at base camps leading to the deposition of cones scales and hulls at these sites. In contrast, only initial stages of pinyon processing should have occurred at temporary pinyon camps, leaving only pine cones and scales.

Investigations of the Pacific Crest Trail sites failed to produce radiocarbon dates of pinyon macrofossils older than 1350 B.P., and it was not found that pinyon macrofossils varied as expected by pinyon camp type. However, their insightful consideration of pinyon camp variability clearly anticipated Binfords' (1980) forager–collector model and Thomas' (1983a, 1985) application of the model to Great Basin ethnographic cases. They pointed out how logistic and residential mobility strategies for pinyon procurement could affect pinyon-juniper settlement patterns in ways that had not been anticipated in previous considerations of the ethnographic record.

Nevertheless, the forager–collector model offered no satisfactory explanation for the change of pinyon procurement strategies over time or for anticipating circumstances where logistic or residential pinyon procurement should occur. For example, Thomas could not explain why some ethnographic groups residentially "mapped onto" pinyon (i.e., Kawich Mountain and Reese River Valley Shoshone), whereas others resided elsewhere and logistically collected pinyon (i.e., Owens Valley and Carson Sink Paiute) in a manner that allowed predicting the mode of prehistoric pinyon procurement in prehistoric Monitor Valley (Thomas 1983a: 156–165; 1983b: 514–516).

Despite 30 years of archaeological research devoted to procuring direct subsistence evidence, paleoenvironmental data, and additional surveys of pinyon-juniper woodlands, the regional variability in pinyon-juniper settlement patterns remains unexplained in any satisfying way. Neither ethnographic descriptions nor the forager–collector model offer robust, testable expectations of the reasons that such variability should occur.

CONTRIBUTIONS OF BEHAVIORAL ECOLOGY APPROACHES BASED ON FORAGING THEORY

It is in this research milieu that various scholars began to consider the economic cost–benefits of pinyon use from the theoretical framework of behavioral ecology. In the earliest of these, Simms (1985) applied general principles of the diet breadth model to predict how prehistoric hunter-gatherers modified their subsistence-settlement strategies in response to the Holocene expansion of pinyon. Harvesting experiments demonstrated that pinyon nuts yield higher caloric return rates than many seeds recovered from archaeobotanical contexts that predate the expansion of pinyon into the central and northern Great Basin (Table 8.1). Thus, according to the prediction of the diet breadth model that optimal foragers raise their overall foraging return rate by taking high-ranked resources whenever they come across them, Simms reasoned that Great Basin hunter-gatherers should have added pinyon to their diet as soon as nuts were locally available. Based on experimental postencounter rates, it seemed unlikely that the variability of pinyon-juniper settlement patterns reflected simple use or nonuse of pinyon as a dietary item, an assessment subsequently supported by recovery of 6700-year-old pinyon hulls from Danger Cave (Rhode and Madsen 1998). Instead, such variability must pertain to the intensity and organization of pinyon usage. Initiating the research tack followed in this chapter, Simms posed the costs necessary to transport pinyon to residential bases as an economic constraint that caused the variation observed among archaeological site distributions in various pinyon woodlands.

Jones and Madsen (1989) devised a measure of the relative transportability of different resources for the maximum transport distance (MTD) that a burden carrier could fill and carry a standardized volume of a resource before incurring a net caloric loss (Table 8.1). They found that MTD ranged from 829 to 0 km for various Great Basin resources; pinyon with a high MTD (812 km) may be economically procured logistically, whereas resources such as pickleweed that has a low MTD (0 km) are better candidates for acquisition by foraging (Jones and Madsen 1989).[2]

In Table 8.1, calculations of the MTD have been modified to reflect uphill and downhill transport costs.[3] Madsen and Jones assume a constant uphill gradient of 3% that, though suitable for a general comparison of resources, is misleading when applied to the Great Basin where the elevation of vegetation communities places resources in consistent topographic relationships with each other. As can be seen in the table, grade greatly affects the caloric costs of travel and transport (Brannon 1992; Zeanah 2000). Because it is unlikely that Great Basin hunter-gatherers ever faced the prospect of transporting pinyon nuts uphill to a shadscale patch, a more realistic ranking of the relative portability of pinyon and shadscale would be the downhill MTD of pinyon (2272 km) and the uphill MTD of shadscale (297 km).

Barlow and Metcalfe (1996; Metcalfe and Barlow 1992) modeled the extent of field processing for resources necessary to obtain and transport the resource optimally, dependent on the round-trip distance between home bases and pinyon patches. Their model assumes that central place foragers maximize the utility of packages returned home, compared with effort expended in field processing and transport. Resources consist of high utility (the edible seed in the case of pinyon) and low utility parts (i.e., cones, cone

[2]Note that these figures are not meant to estimate the actual distance that Great Basin hunter-gatherers carried resources. Obviously, the distance that a collector should logistically procure a distant resource is constrained by the return of resources close at hand (Rhode 1990b) and the return for simply moving to the distant resource patch (see Kelly 1990).

[3]Calculations for uphill and downhill transport assume the following caloric cost constants derived from MacDonald (1961).

Table 8.1. Caloric Return Rate (kcal/h) and Maximum Transport Distance (km) of Selected Great Basin Resources[a]

Percent Grade	Caloric Cost of Walking Per Km	Caloric Cost of Carrying 1 Kg Per Km
−10	36.6	0.42
10	115.2	1.32

[a]Simms 1987; Jones and Madsen 1989; Zeanah 2000.

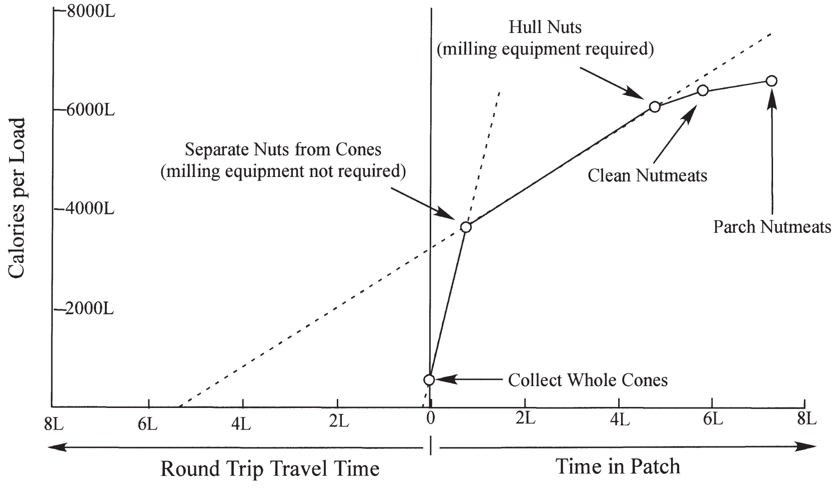

Figure 8.3. Changes in the utility of pinyon with field processing time. The dashed lines drawn through the *x* axis indicate hours of round-trip travel time between a central place and the pinyon grove when removing pine nuts from cones and hulling pine nuts (Barlow and Metcalfe 1996).

scales, and hulls) that can be discarded either at home or at the field processing location. The goal of field processing is to increase the utility of a transported load by culling low utility parts, but too much field processing reduces the number of trips that foragers can make to and from the resource patch. A central place forager must trade off the number of trips and the utility of each load to optimize the return rate of a resource transported home.

The round-trip distance between the central place and the patch determines the extent of field processing worthwhile, more processing is expected as the distance increases. Barlow and Metcalfe (1996) used their model to predict field processing decisions for pinyon nuts, as illustrated in Figure 8.3. The *y* axis illustrates the utility of pinyon (in calories per kilogram) samples at each processing stage. The *x* axis shows time spent procuring and field processing pinyon to the right of the *y* axis, and round-trip travel time is to the left. Based on calculations for 15-kg loads, Barlow and Metcalfe predict that hunter-gatherers can economically transport cones and cones scales back to residential bases that are no more than 2.5 km away from the pinyon grove. In contrast, they can profitably hull and clean nut meats in the field only if the transport distance back home exceeds 120 km.

The Barlow and Metcalfe field processing model mathematically formalized Rhode's (1980) intuitive expectations for the deposition of pinyon

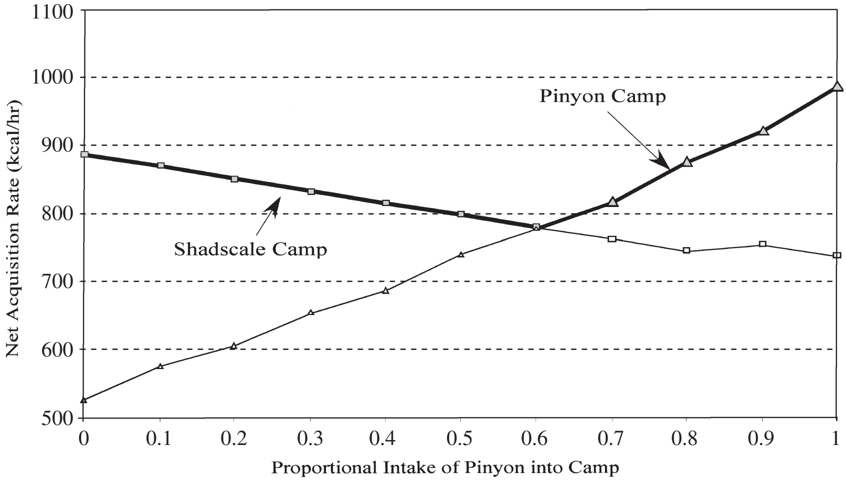

Figure 8.4. Central place settlement model for pinyon-juniper and lowland shadscale base camps based on proportional intake of pinyon into camp (Zeanah 2000).

macrofossils and grounded them firmly within the theoretical framework of behavioral ecology. Model predictions received strong empirical support from the frequent recovery of pinyon seed hulls, but not scales, from archaeobotanical contexts outside of pinyon woodlands (Basgall and McGuire 1988; Madsen 1979; Rhode and Madsen 1998; Scharf 1992; Wells 1983). The field processing model also holds implications for the optimal location of central place base camps. When spatially discrete resources are used from the same central place, transport costs should tether residential camps to patches of resources that cannot be field processed into high utility loads (Barlow and Metcalfe 1996; see Bettinger et al. 1997).

Zeanah (1996, 2000) developed a transport cost model that predicts where central place hunter-gatherers should reside when they provision camp from two spatially discrete resource patches and have the option to camp at one resource patch and logistically use the other. In Figure 8.4, the model is cast for two hypothetical winter villages where food stores are filled with pinyon and shadscale. Because harvesting experiments indicate that pinyon is a resource ranked slightly higher, the model assumes that hunter-gatherers should supply the winter village with as many nuts as the abundance of the crop will allow and make up any deficit by procuring shadscale seed. Then, central place foraging return rates can be calculated for both locations under different scenarios of pinyon procurement by subtracting procurement and transport costs obtained from each camp from a gross caloric requirement and dividing by the time necessary for procurement and transport.[4] Hunter-gatherers should choose the camp location with highest net acquisition rates after transport. Three important things are apparent about this simulation.

First, the model closely reproduces the winter village location decision described by Steward (1938: 28, 52–53, 65, 118, 142, 157); Great Basin hunter-gatherers chose to overwinter in woodlands if the pinyon harvests were sufficiently large but shifted camp elsewhere and logistically transported pinyon back to camp when harvests were small. Second, the portability of pinyon strongly influences net acquisition rates obtainable from different camps. Although pinyon and shadscale have comparable postencounter caloric return rates (1400 and 1200 kcal/h, respectively), the greater portability of pinyon makes it necessary for the pinyon harvest to exceed 60% of the caloric requirement to make residence at the pinyon camp more economical than the shadscale camp. If pinyon comprises less than 60% of the caloric intake of the camp, central place foragers achieve a higher net acquisition rate by residing near shadscale and logistically transporting pinyon. Finally, the central place foraging model directly links the forager–collector model with issues of diet breadth and subsistence intensification. As diet breadth expands to include spatially dispersed resources, the economics of central place foraging pull residential bases to less portable

[4] The formula for calculating net acquisition rates is as follows:

$$\frac{R + \sum_{i=1}^{2}\left[FN_i * C_{\mathrm{h}} + \left(\sum_{s=1}^{n} D_{is} * NN_i * W_s\right) + \left(\sum_{s=1}^{n} D_{if} * NN_i * L_i * T_s\right)\right]}{\sum_{i=1}^{2}\left(FG_i + \dfrac{\sum_{s=1}^{n} D_{is} * NG_i}{V}\right)},$$

where

R = net caloric requirement during period of camp occupation;
FN_i = handling time (hours) for total loads of resource i comprising net caloric requirement;
FG_i = handling time (hours) for total loads of resource i comprising net caloric requirement plus additional loads required to cover caloric costs;
C_h = caloric cost of handling resources (300 kcal/h);
D_{is} = distance of slope s to and from nearest patch of resource i (km);
D_{if} = distance of slope f from nearest patch of resource i (km);
NN_i = number of loads of resource i transported comprising net caloric requirement;
NG_i = number of loads of resource i transported comprising net caloric requirement plus additional loads required to cover caloric costs;
W_s = caloric costs of walking across grade s (kcal/km);
L_i = total weight of one load of resource transported (max. = 25 kg);
T_s = caloric costs of carrying load across grade s (kcal/km);
V = walking speed (3 km/h).

resources that contribute significantly to the dietary intake of the camp. Highly portable resources, such as pinyon, are likely to witness a shift from residential to logistic usage as diet breadth expands (Zeanah 2000).

APPLICATION OF MODELING INSIGHTS

One aspect of spatial and temporal variability among prehistoric pinyon procurement strategies that has vexed Great Basin archaeologists for decades is the abundance of groundstone milling equipment in pinyon-juniper woodlands. Milling slabs and handstones are ubiquitous in pinyon-juniper forests of Owens Valley (Bettinger 1976, 1977; Delacorte 1990). However, in many other parts of the Great Basin, the rarity of ground stone tools is not in keeping with the ethnographically documented importance of pinyon as a food resource in the same regions (Thomas 1973; Thomas and Bettinger 1976; Simms 1985; Kelly 2001; Bettinger 1999b). Contending explanations for the phenomenon are either that pinyon usage developed relatively recently in forests where ground stone tools are rare (Bettinger 1999b), or that tool curation, scavenging, and site looting have artificially depressed the quantities of ground stone tools in some woodlands (Thomas and Bettinger 1976; Simms 1985).

Central place foraging models suggest a new explanation for the differential abundance of milling equipment. Ethnographically (Chamberlin 1911; Coville 1892; Dutcher 1893; Wheat 1967), ground stone tools were used to remove hulls from pinyon seeds and grind seeds into flour (Fig. 8.5). The Barlow and Metcalfe field processing model (Fig. 8.3) suggests that these processing steps should be economically undertaken only at a home base or when the pinyon is to be transported for distances that far exceed those typical of ethnographic Great Basin foragers (see Rhode 1990b). The transport cost and central place location models suggest that pinyon harvests must be relatively high to make residing in pinyon zones more economical than in lowland residence. If these inferences are correct, then the rarity of milling equipment in many Great Basin woodlands simply reflects different decisions of whether to reside in pinyon zones or to procure and transport pinyon logistically.

Such regional differences in the tendencies to reside in pinyon-juniper woodlands might reflect local variability in the quantity of harvested nuts.[5] One regional classification of Great Basin pinyon-juniper woodlands

[5] The local presence of sufficient quantities of resources higher ranked or more portable than pinyon would also lead to a decision not to camp in pinyon woodlands (see Delacorte et al. 1992; Kelly 1995), irrespective of the quantity of the local pinyon crop.

Figure 8.5. Two-handed huller being used to shell pine nuts on a wooden metate. Ground stone tools are likely to have been used to process pinyon only at base camps or when logistic transport distances were exceptionally large. Photograph by Margaret Wheat, 1958. Margaret Wheat Collection, Special Collections, University of Nevada-Reno Library.

reveals that the composition of pinyon-juniper woodlands varies across the Great Basin in ways that correlate with archaeological patterns (West et al. 1998). In the study, 463 woodland plots 20×50 m in 66 Great Basin mountain ranges were compared for the proportional composition of pinyon and juniper.[6] The study documented tremendous regional variability both within and between mountain ranges but revealed one consistent regional

[6]At a minimum, plots had to contain at least 25 pinyon or juniper trees with at least one fully mature tree, and no evidence of recent cutting, chaining, or burning. These criteria ensured sampling of comparable stands at least 50 years old.

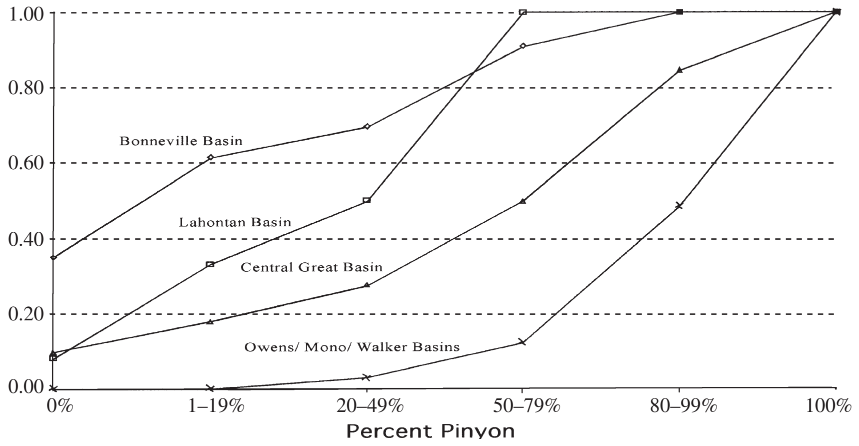

Figure 8.6. Percent pinyon in woodlands of four geographic regions of the Great Basin (West et al. 1998).

trend. Woodlands in the western, central, and southern portions of the Great Basin are richer in pinyon trees than comparable stands in the northern and eastern Great Basin (Fig. 8.6). For example, 56% of the stands sampled in the Walker, Mono, and Owens River Basins of the western Great Basin are pure pinyon woodlands. In central Great Basin ranges, 16% of the stands are pure pinyon, but a further 57% are at least 50% pinyon. In the Lahontan and Bonneville/Upper Humboldt basins, juniper dominates woodlands (respectively, 50% and 71% of the stands bear less than 50% pinyon). These regional trends appear to result from the role of Pacific winter storm fronts in inhibiting pinyon growth (Beeson 1972; West et al. 1978).

Obviously, differences in the proportional representation of pinyon in woodlands will not translate directly to the productivity of pinyon harvests; a pure but sparse stand of pinyon might produce smaller crops than a dense stand dominated by juniper. However, available data support a relationship; in a poor cone production year, Jordan (1974) inventoried an average yield of 681 cones per acre in a woodland tract of pure pinyon but only 553 cones per acre in a comparable tract of 77% pinyon trees. Figure 8.7 shows estimated favorable year productivity of pine nut harvests for 29 Nevada ecological sites bearing pinyon (Soil Conservation Service 1992a,b,c,d, 1993). The estimates reveal considerable variability in the size of the seed crop (ranging from 30 to more than 330 kg/ha) and reveal a significant positive correlation between crop size and percentage coverage by pinyon.

Figure 8.8 illustrates the effect of pinyon density on pinyon-juniper settlement decisions. Ethnographic accounts indicate that a family of Great

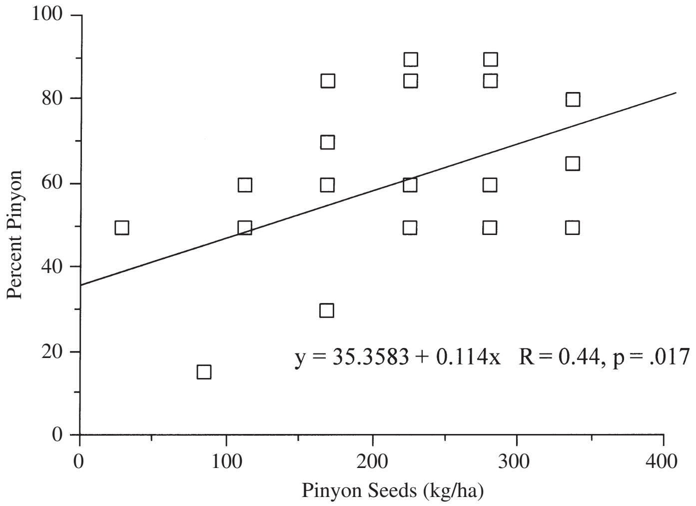

Figure 8.7. Pine nut productivity by percentage Pinyon for 29 Nevada ecological sites.

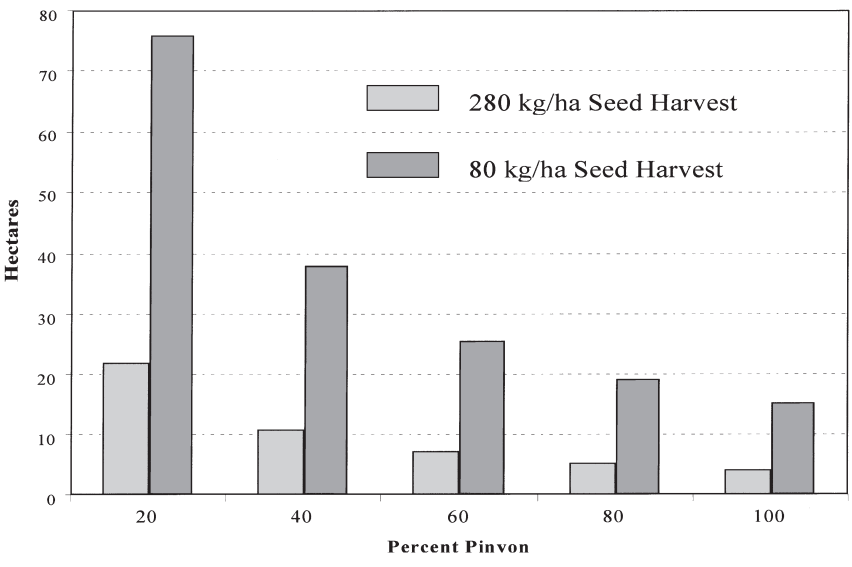

Figure 8.8. Area (hectares) required to harvest 680 kg of clean pinyon seeds with 280 kg/ha and 80 kg/ha crop yields.

Basin hunter-gatherers could store about 680 kg of pinyon nuts in a good year (Cook 1941; Price 1962; Steward 1938), but harvests could range from 45 to 275 kg in less productive years (Cook 1941: 54). A typical pinyon nut harvest in a favorable year is about 280 kg/ha (Fischer and Montano 1977; Jeffers 1994). Figure 8.8 indicates the area required to harvest 680 kg of clean pinyon seed for maximum harvests of 280 kg/ha and 80 kg/ha of unhulled nuts in pure pinyon woodlands, scaling the harvest size by the proportion of pinyon in the woodland and assuming that prehistoric hunter-gatherers lose none of the crop to spoilage or competitors. For favorable pinyon harvests, less than twenty hectares can provide an entire winter food supply, even in forests of 20% pinyon. However in years of a more moderate harvest of 80 kg/ha,[7] 15 hectares of pure pinyon woodlands could supply the winter larder, but more than 75 hectares would be necessary in woodlands of 20% pinyon.

More diffuse pinyon crops in hilly terrain encourage placement of residential bases in lowland areas below the pinyon-juniper woodland and make it less likely that camp spots in pinyon woodlands will recurrently be the most economic locations for winter villages. If so, differences in the relative richness of pinyon will correlate with the density of ground stone tools in woodlands; ground stone will be relatively rare in woodlands that have low densities of pinyon because those woodlands are less likely to serve recurrently as suitable winter occupation locations.

Table 8.2 arrays data on ground stone tool distributions in nine surveys of Great Basin woodlands. The span of time that pinyon has been available in these areas does not account for ground stone tool densities. Pinyon has probably grown in the northeastern (Deep Creek, Toano, and Pequop Ranges) and central Great Basin (Toquima, Shoshone, Toiyabe, and Monitor Ranges) for the last 6000 years and arrived in the northern (Cortez Range) and northwestern (Stillwater Mountains) area only in the last few millennia. Yet ground stone tool densities are higher in the Stillwater and Cortez Mountains than in any of the central or northern ranges. Neither does the antiquity of pinyon procurement inferred from archaeological evidence explain ground stone densities. Pinyon camps in Owens and Deep Springs Valleys postdate 1350 B.P., yet ground stone occurs in much higher densities there than in the Reese River Valley (where pinyon camps, it is inferred, are much older) or in the northeastern Great Basin ranges (where hulls from Danger Cave prove that pinyon was consumed 6700 years ago).

Data on the proportion of pinyon in plots sampled in pinyon-juniper forests adjacent to eight of the surveys (West et al. 1998) are presented in Table 8.3 and ranked for overall pinyon density. Comparison of these data

[7]An 80-kg/ha harvest would be about the maximum yield of 2500 cones per acre observed in a 5 year study of a sample plot in northern Utah (Lanner 1983).

Table 8.2. Groundstone Tool Densities in Pinyon Juniper Woodland Surveys

Survey	Ground Stone Tools	Survey Area (hectares) in Pinyon-Juniper Woodlands	Groundstone Tools per Hectare
Owens Valley	60	775	0.0774
Deep Springs	32	750	0.0427
Reese River	10	1000	0.0100
Stillwater	22	968	0.0227
Toano Draw	15	1984	0.0076
Deep Creek	3	448	0.0067
Monitor Valley	36	4775	0.0075
Cortez	23	1152	0.0200
Walker Lake Uplands	4	192	0.0208
Grass Valley	29	1000	0.0290

with ground stone densities reveals a strong, significant correlation between the proportion of pinyon and the number of ground stone tools per hectare (Kendall's tau = .74, $p = .0133$). Consistent with expectations based on the central place foraging models, pinyon productivity accounts for ground stone tool densities in pinyon-juniper woodlands better than the span of pinyon availability or the antiquity of pinyon procurement.

The Owens Valley Case

Despite the regional correlation between ground stone and pinyon densities, variations in pinyon productivity cannot account for all spatial and temporal diversity among pinyon-juniper settlement patterns. Local differences in the availability of alternative resources, paleoenvironmental change, and long-term trends in population growth and resource intensification must also influence the pinyon use strategy in any particular time and place. However, a theoretical understanding of the economics of central place foraging provides a context from which to compare local trends in the archaeological record against particular resource distributions. This is best illustrated by Owens Valley where some of the richest pinyon forests of the Great Basin contain high densities of ground stone, yet lack pinyon camps until 1350 B.P. (Bettinger 1977, 1989; Delacorte 1990). What factors account for the relatively late but intensive development of pinyon camps in this region?

The intensive post-1350 B.P. usage of pinyon suggested by high ground stone tool densities is consistent with the ethnographic record, which shows that Owens Valley supported one of the highest population densities in the

Table 8.3. Relative Ranking of Pinyon Densities by Adjacent Mountain Range (West et al. 1998)

Survey	Mountain Range	Total Inventoried Plots	100% Pinyon	80–99% Pinyon	50–79% Pinyon	20–49% Pinyon	1–19% Pinyon	No Pinyon %	Relative Rank
Owens Valley/ Deep Springs	White Mountains	7	71	14	14	0	0	0	1
Walker Lake Uplands	Wassuk and Pine Grove Mountains	17	47	35	12	6	0	0	2
Reese River	Toiyabe and Shoshone Ranges	27	48	33	11	4	0	4	3
Grass Valley	Toiyabe Range and Simpson Park Mountains	13	8	76	0	8	8	0	4
Monitor Valley	Toquima and Monitor Mountains	14	14	36	50	0	0	0	5
Toano Draw	Toana and Pequop Ranges	9	0	11	56	11	11	11	6
Deep Creek	Deep Creek Mountains	8	0	25	38	0	38	0	6
Stillwater	Stillwater Mountains	No Data	–	–	–	–	–	–	–
Cortez	Cortez Mountain	No Data	–	–	–	–	–	–	–

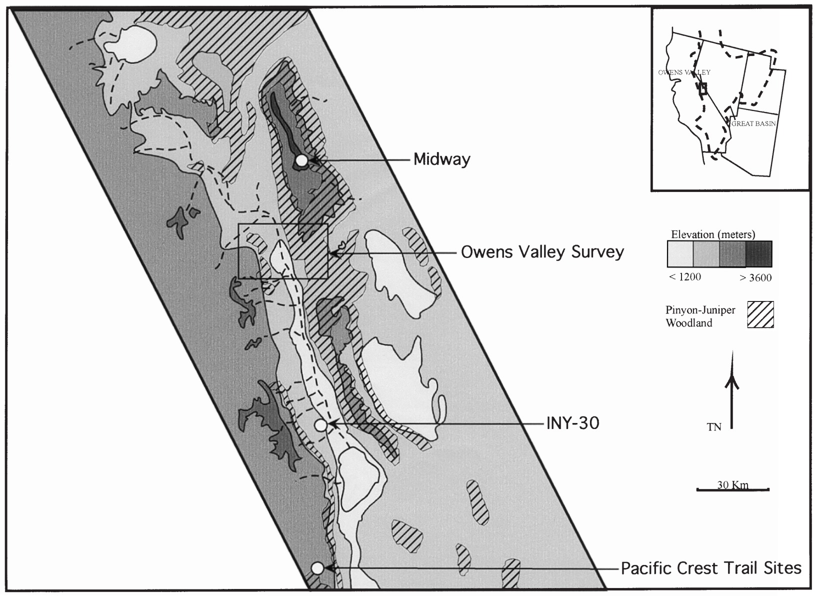

Figure 8.9. Map of Owens Valley and surrounding areas showing the locations of Bettinger's Owens Valley survey and sites yielding evidence of pre-1350 B.P. pinyon usage.

Great Basin and that pinyon was an important overwinter food resource (Steward 1933, 1938). Yet archaeological research in Owens Valley shows that the ethnographic pattern developed only 1350 years ago as a consequence of subsistence-settlement intensification in response to population growth (Basgall and McGuire 1988; Bettinger 1977, 1989; Delacorte 1990, 1999). Figure 8.9, a map of Owens Valley and adjacent Mono Basin and Coso Range regions, shows the approximate location of Bettinger's (1977) Owens Valley survey, which is about the size of an ethnohistoric territory (Steward 1933: map 1). Analyses of obsidian distributions and assemblage composition and diversity reveal that pre-1350 B.P. settlement systems probably encompassed the entire region illustrated on the map (Basgall 1989; Basgall and McGuire 1988; Bettinger 1999a; Delacorte 1999). Clearly, the Owens Valley survey was not designed to sample site variability adequately in the earlier settlement pattern. Confronted with differences in the mobility of this scale, the possibility must be considered that archaeologists have simply not looked in the right place for evidence of pre-1350 B.P. pinyon usage.

Seasonality data from a limited set of pre-1350 B.P. faunal and floral assemblages are evidence that earlier hunter-gatherers overwintered near Owens Lake and the Coso Range (Basgall and McGuire1988: 321, 348) and traversed the central and northern regions in summer and early fall (Scharf

1992). If so, evidence for pre-1350 B.P. pinyon use should occur in the southern portion of the region, but studies that support a 1350 B.P. inception of pinyon use have been done predominantly in central and northern Owens Valley (Bettinger 1976, 1977, 1989; Delacorte 1990).

Figure 8.9 also indicates the locations of the Pacific Crest Trail sites that have been proposed to represent pre-1350 B.P. pinyon camps (Garfinkel et al. 1980; McGuire and Garfinkel 1980) and two sites that have yielded archaeobotanical pinyon hulls from pre-1350 B.P. contexts (Basgall and McGuire 1988; Scharf 1992). Certainly, this suggests that some of the best evidence for pre-1350 B.P. pinyon usage (the Pacific Crest Trail pinyon camps and site CA-INY-30) comes from southern Owens Valley. Also note that the two sites bearing pre-1350 B.P. pinyon hulls (Midway and CA-INY-30) are located outside of pinyon woodlands, suggesting that pre-1350 B.P. hunter-gatherers in Owens Valley logistically procured and transported to camps outside of pinyon-juniper woodlands.

Post-1350 B.P. pinyon camps in central Owens Valley characteristically contain habitation structures, storage features, and ground stone tools (Bettinger 1977, 1989) that reflect the preparation, storage, and consumption of pinyon at residential bases, rather than field processing of pinyon at logistic camps. If so, the 1350 B.P. appearance of pinyon camps in central Owens Valley marks the beginning of residential occupation of pinyon woodlands in central Owens Valley, not necessarily the inception of pinyon usage in the entire region. However, a shift from logistic to residential pinyon procurement strategies appears to contradict central place foraging models. Pinyon should be a more economical target for logistic exploitation when less transportable resources, such as lowland seeds, must also be garnered from the same central place.

One possible explanation for the discrepancy pertains to the intensity and organization of pinyon usage in Owens Valley after 1350 B.P. Known pre-1350 B.P. occupation sites occur only on the valley floor and usually appear to be short-term, transient camps (Basgall and Giambastiani 1995; Bettinger 1977, 1991b; Bettinger et al. 1984; Delacorte 1990, 1999). Residential sites bearing rock-ring habitation structures that suggest prolonged, seasonal occupation have been found only in southern Owens Valley (Basgall and McGuire 1988). In contrast, post-1350 B.P. residential sites always contain high investment features, such as rock-ring floors, storage features, plant processing facilities, and refuse middens. These sites also contain a more eclectic array of plant, animal, and tool stones than their earlier counterparts, but they frequently originate from within a smaller catchment radius of each base camp (Basgall and McGuire 1988; Bettinger 1989, 1991b; Delacorte 1999). Post-1350 B.P. base camps occur throughout Owens Valley region and appear in upland vegetation communities for the first time

(Basgall and Giambastiani 1995; Bettinger 1977, 1989, 1991b; Delacorte 1990). Therefore, the 1350 B.P. appearance of pinyon camps in central Owens Valley represents only one element of a regional subsistence-settlement shift that marked an expansion of residential site locations into multiple vegetation communities, a constriction of the catchment basins exploited from residential sites, and an intensification of subsistence strategies.

This transition ultimately led to the semisedentary and territorial settlement patterns observed ethnographically in Owens Valley (Steward 1933; Thomas 1983a: 32–34). The regional archaeological record suggests that growing populations quickly filled every habitable location in Owens Valley, constraining both logistic and residential mobility (see Steward 1933: map 1). In this context, the 1350 B.P. appearance of residential occupation sites in the pinyon-juniper woodlands of central Owens Valley may reflect the choice of hunter-gatherers to map onto resource patches that could be more economically used logistically because better base camp locations were already occupied and logistic collecting opportunities constrained.

The data presented in Figure 8.8 shows that small patches of rich pinyon groves can supply an entire winter harvest of nuts, even in years with a relatively poor crop, so long as hunter-gatherers minimize losses to spoilage and competing foragers. One effective ethnographically documented strategy for maximizing the seed crops yielded from a grove of pinyon trees was to harvest green, unopened cones (Bettinger 1994; Bettinger and Baumhoff 1983). Procurement of green cones, amassing large overwinter pinyon caches, territorial ownership of pinyon groves, and using alternative, high-cost upland resources are means by which post-1350 B.P. hunter-gatherers intensified their subsistence strategies to make up for the costs of camping in suboptimal base camp locations (Bettinger 1991a; Grayson 1991). Therefore, the 1350 B.P. shift from logistic to residential usage of pinyon woodlands results from circumscription of residential base catchments and restriction of logistic mobility that would result from demographic packing in the central Owens Valley region (Bettinger 1991b; Zeanah 2000).

CONCLUSIONS

Theoretical models of the costs and benefits of central place foraging in the Great Basin have provided the theoretical tools necessary to investigate variability in logistic and residential mobility strategies in the Great Basin. These models reveal no theoretical reason to expect any single strategy of pinyon exploitation as typical of Great Basin hunter-gatherers. Instead, they follow Thomas' lead to model formally how the logistic and residential strategies of hunter-gatherers, equipped with similar technologies and procuring similar resources, might vary in different local landscapes.

The development of transport models in Great Basin subsistence studies illustrates the important role that general explanatory theory can play in such considerations. These models derive from evolutionary theory and bear clear implications for understanding variability in pinyon procurement strategies. They also have test implications for site distributions and assemblage composition that clarify earlier disputes about the relative validity of survey data versus archaeobotanical remains as evidence of prehistoric subsistence. Therefore, they qualify as middle range theory at its best by explicitly subsuming mid-range issues under higher order theory.

REFERENCES

Barlow, K. R., and Metcalfe, D., 1996, Plant Utility Indices:Two Great Basin Examples, *Journal of Archaeological Science* 23:351–371.

Basgall, M. E., 1989, *Obsidian Acquisition and Use in Prehistoric Central Eastern California*, edited by R. E. Hughes. Contributions of the University of California Research Facility No. 48.

Basgall, M. E., and Giambastiani, M. A., 1995, *Prehistoric Use of a Marginal Environment:Continuity and Change in Occupation of the Volcanic Tablelands, Mono and Inyo Counties California*. Center for Archaeological Research at Davis Publication No. 12, University of California, Davis.

Basgall, M. E., and McGuire, K. R., 1988, *The Archaeology of CA-INYO-30:Prehistoric Culture Change in Southern Owens Valley, California*. Far Western Anthropological Research Group, Inc., Davis, CA.

Beeson, C. D., 1972, *The Distribution and Synecology of Great Basin Pinyon-Junipers*, M.S. Thesis, University of Nevada, Reno.

Bettinger, R. L., 1976, The Development of Pinyon Exploitation in Central Eastern California. *Journal of California and Great Basin Anthropology* 3(1):81–95.

Bettinger, R. L., 1977, Aboriginal Human Ecology in Owens Valley:Prehistoric Change in the Great Basin. *American Antiquity* 42(1):3–17.

Bettinger, R. L., 1981, Settlement Data and Subsistence Systems. *American Antiquity* 46:640–643.

Bettinger, R. L., 1989, *The Archaeology of Pinyon House, Two Eagles, and Crater Middens:Three Residential Sites in Owens Valley*. Anthropological Papers 67. American Museum of Natural History, New York.

Bettinger, R. L., 1991a, *Hunter-Gatherers:Archaeological and Evolutionary Theory*. Plenum, New York.

Bettinger, R. L., 1991b, Aboriginal Occupation at High Altitude:Alpine Villages in the White Mountains of Eastern California. *American Anthropologist* 93(3):656–679.

Bettinger, R. L., 1994, How, When, and Why Numic Spread. In *Across the West:Human Populations Movement and the Expansion of the Numa*, edited by D. B. Madsen and D.R. Rhode, pp. 44–55. University of Utah Press, Salt Lake City.

Bettinger, R. L., 1999a, From Traveler to Processor:Regional Trajectories of Hunter-Gatherer Sedentism in the Inyo-Mono Region, California. In *Settlement Pattern Studies in the Americas; Fifty Years Since Viru*, edited by B. R. Billman and G. M. Feinman, pp. 39–55. Smithsonian Institution Press, Washington.

Bettinger, R. L., 1999b, What Happened in the Medithermal. In *Models for the Millennium:Great Basin Anthropology Today*, edited by C. Beck, pp. 62–74. University of Utah Press, Salt Lake City.

Bettinger, R. L., and Baumhoff, M. A., 1983, Return Rates and Intensity of Resource Use in Numic and Prenumic Adaptive Strategies. *American Antiquity* 48:830–834.

Bettinger, R. L., Delacorte, M., and McGuire, K. R., 1984, Archaeological Excavations at the Partridge Ranch Site (CA-INY-2146), Inyo County, California. Submitted to California Department of Transportation, Sacramento.

Bettinger, R. L., Malhi, R., and McCarthy, H., 1997, Central Place Models of Acorn and Mussel Processing. *Journal of Archaeological Science* 24(10):887–899.

Binford, L. R., 1964, A Consideration of Archaeological Research Design. *American Antiquity* 29:425–441.

Binford, L. R., 1980, Willow Smoke and Dog's Tails:Hunter-Gatherer Settlement Systems and Archaeological Site Formation. *American Antiquity* 45(1):4–20.

Brannon, J. A., 1992, On Modeling Resource Transport Costs:Suggested Refinements. *Current Anthropology* 33(1):56–60.

Chamberlin, R. V., 1911, The Ethno-Botany of the Goisute Indians of Utah. *American Anthropological Association Memoirs* 2:331–404.

Cook, S. F., 1941, The Mechanisms and Extent of Dietary Adaptation Among Certain Groups of California and Nevada Indians. *Ibero-Americana* 18:1–59.

Coville, F. V., 1892, The Panamint Indians of California, *American Anthropologist* 5:351–361.

Delacorte, M. G., 1990, *Prehistory of Deep Springs Valley, Eastern California:Adaptive Variation in the Western Great Basin*, Ph.D. Dissertation, University of California, Davis.

Delacorte, M. G., 1999, The Changing Role of Riverine Environments in the Prehistory of the Central-Western Great Basin:Data Recovery Excavations at Six Prehistoric Sites in Owens Valley, California, Far Western Anthropological Research Group, Inc. Submitted to CALTRANS District 9.

Delacorte, M. G., Gilreath, A., and Hall, M. C., 1992, A Class II Sample Survey for the Cortez Cumulative Effects Study Area, Lander and Eureka Counties, Nevada, Far Western Anthropological Research Group. Submitted to U.S. Department of Interior, Bureau of Land Management, Battle Mountain and Elko Districts, Nevada.

Dutcher, B. H., 1893, Pinyon Gathering Among the Panamint Indians, *American Anthropologist* 6:376–380.

Fischer, J. T., and Montano, J. M., 1977, Management of Pinyon for Ornamentals, Christmas Trees, and Nut Production. In *Ecology, Uses, and Management of Pinyon-Juniper Woodlands*, edited by E. F. Aldon and T. J. Loring, pp. 35–40. General Technical Report 39. USDA Forest Service Rocky Mountain Forest and Range Experimental Station, Albuquerque.

Garfinkel, A. P., Schiffman, R. A., and McGuire, K. R., 1980, Archaeological Investigations in the Southern Sierra Nevada:The Lamont Meadow and Morris Peak Segments of the Pacific Crest Trail. Bureau of Land Management (California) Cultural Resources Publications in Archaeology, Bakersfield.

Grayson, D. K., 1991, Alpine Faunas from the White Mountains, California, Adaptive Change in the Late Pleistocene Great Basin. *Journal of Archaeological Science* 18:483–506.

Grayson, D. K., 1993, *The Desert's Past. A Natural Prehistory of the Great Basin*. Smithsonian Institution Press, Washington, DC.

Jeffers, R. M., 1994, Piñon Seed Production, Collection, and Storage. In Desired Future Conditions for Pinyon-Juniper Ecosystems, edited by D. W. Shaw, E. F. Aldon, and C. Losapio, General Technical Report 258. USDA Forest Service Rocky Mountain Forest and Range Experimental Station, Ogden, UT.

Jennings, S. A., and. Elliott-Fisk, D. L., 1993, Packrat Midden Evidence of Late Quaternary Vegetation Change in the White Mountains. *Quaternary Research* 39:214–221.

Jones, K. T., and Madsen, D. B., 1989, Calculating the Cost of Resource Transportation, *Current Anthropology* 30:529–534.

Jordan, M., 1974, *An Inventory of Two Selected Woodland Sites in the Pine Nut Hills of Western Nevada*, M.A. Thesis, University of Nevada, Reno.

Kelly, R. L., 1990, Marshes and Mobility in the Western Great Basin. In *Wetland Adaptations in the Great Basin*:Papers from the Twenty-First Great Basin Anthropological Conference, Museum of Peoples and Cultures Occasional Papers No. 1. Brigham Young University, Provo, pp. 258–276.

Kelly, R. L., 1995, Hunter-Gatherer Lifeways in the Carson Sink:A Context for Bioarchaeology. In *Bioarchaeology of the Stillwater Marsh:Prehistoric Human Adaptation in the Western Great Basin*, edited by C. S. Larson and R. L. Kelly, Anthropological Papers, Vol. 58, Part 1. American Museum of Natural History, New York.

Kelly, R. L., 2001, *Prehistory of the Carson Desert and Stillwater Mountains:Environment, Mobility, and Subsistence in a Great Basin Wetland*. University of Utah Anthropological Papers Number 123, Salt Lake City.

Lanner, R. M., 1983, The Expansion of Singleleaf Piñon in the Great Basin. In *The Archaeology of Monitor Valley 2. Gatecliff Shelter*, edited by D. H. Thomas, pp. 167–171. Anthropological Papers, Vol. 59, Part 1, American Museum of Natural History, New York.

Lindsay, L. W., and Sargent, K., 1979, *Prehistory of the Deep Spring Mountain Area, Western Utah*. Antiquities Section Selected Papers No. 114, Utah Division of State History, Salt Lake City.

MacDonald, I., 1961, Statistical Studies of Recorded Energy Expenditure of Man. *Nutrition Abstracts and Reviews* 31(3):739–757.

Madsen, D. B., 1979, Prehistoric Occupation Patterns, Subsistence Adaptations, and Chronology in the Fish Springs Area, Utah. In Archaeological Investigations in Utah, edited by D. B. Madsen and R. E. Fike. Cultural Resource Series No. 12, Bureau of Land Management, Salt Lake City.

Madsen, D. B., 1981, The Emperor's New Clothes. *American Antiquity* 46:637–540.

Madsen, D. B., 1986, Great Basin Nuts. In *Anthropology of the Desert West:Essays in Honor of Jesse D. Jennings*, edited by C. J. Condie and D. D. Fowler, pp. 21–41. University of Utah Anthropological Papers No 110, Salt Lake City.

McGuire, K., and Garfinkel, A. P., 1976, Comment on "The Development of Pinyon Exploitation in Central Eastern California", *Journal of California Anthropology* 3(2):83–85.

McGuire, K., and Garfinkel, A. P., 1980, Archaeological Investigations in the Southern Sierra Nevada:The Bear Mountain Segment of the Pacific Crest Trail. Bureau of Land Management (California) Cultural Resources Publications in Archaeology, Bakersfield.

Metcalfe, D., and Barlow, K. R., 1992, A Model for Exploring the Optimal Trade-off between Field Processing and Transport. *American Anthropologist* 94:349–356.

Price, J. A., 1962, *Washoe Economy*. Nevada State Museum Anthropological Papers 6, Carson City, NV.

Rhode, D., 1980, Plant Macrofossils. In Archaeological Investigations in the Southern Sierra Nevada:The Lamont Meadow and Morris Peak Segments of the Pacific Crest Trail, edited by A. P. Garfinkel, R. A. Schiffman, and K. R. McGuire, Bureau of Land Management (California) Cultural Resources Publications in Archaeology, Bakersfield.

Rhode, D., 1990a, Settlement Patterning and Residential Stability at Walker Lake, Nevada:The View From Above. In *Wetland Adaptations in the Great Basin*:Papers from the Twenty-First Great Basin Anthropological Conference, Museum of Peoples and Cultures Occasional Papers No. 1, Brigham Young University, Provo, pp. 107–120.

Rhode, D., 1990b, On Transportation Costs of Great Basin Resources:An Assessment of the Jones–Madsen Model. *Current Anthropology* 31:413–419.

Rhode, D., 1999, The Role of Paleoecology in the Development of Great Basin Archaeology and Vice Versa. In *Models for the Millennium:Great Basin Anthropology Today*, edited by C. Beck, pp. 29–52. University of Utah Press, Salt Lake City.

Rhode, D., and Madsen, D. B., 1998, Pine Nut Use in the Early Holocene and Beyond:The Danger Cave Archaeobotanical Record. *Journal of Archaeological Science* 25: 1199–1210.

Rhode, D., and Thomas, D. H., 1983, Flotation Analysis of Selected Hearths. In *Archaeology of Monitor Valley:2. Gatecliff Shelter*, edited by D. H. Thomas, pp. 151–157. Anthropological Papers, Vol. 59, American Museum of Natural History, New York.

Scharf, E. R., 1992, *The Archaeobotany of Midway:Plant Resource Use at a High Altitude Site in the White Mountains of Eastern California*, M.A., University of Washington.

Simms, S. R., 1985, Pine Nut Use in Three Great Basin Cases:Data, Theory, and a Fragmentary Material Record. *Journal of California and Great Basin Anthropology* 7:166–175.

Soil Conservation Service, 1992a, Major Land Resource Area 25:Owyhee High Plateau, Nevada Site Descriptions. U.S. Department of Agriculture, Reno.

Soil Conservation Service, 1992b, Major Land Resource Area 26:Carson Basin and Mountains, Nevada Site Descriptions. U.S. Department of Agriculture, Reno.

Soil Conservation Service, 1992c, Major Land Resource Area 27:Fallon-Lovelock Area, Nevada Site Descriptions. U.S. Department of Agriculture, Reno.

Soil Conservation Service, 1992d, Major Land Resource Area 29:Southern Nevada Basin and Range, Site Descriptions. U.S. Department of Agriculture, Reno.

Soil Conservation Service, 1993, Major Land Resource Area 28B:Central Nevada Basin and Range, Site Descriptions. U.S. Department of Agriculture, Reno.

Steward, J. H., 1933, Ethnography of the Owens Valley Paiute. In *University of California Publications in American Archaeology and Ethnology*, Berkeley, Vol. 33, pp. 423–438.

Steward, J. H., 1938, *Basin-Plateau Aboriginal Sociopolitical Groups* Bureau of American Ethnology Bulletin No. 120, Smithsonian Institution, Washington, DC.

Steward, J. H., 1941, Culture Element Distributions: XIII. Nevada Shoshone. In:*University of California Anthropological Records*, Berkeley, Vol. 4, pp. 209–259.

Thomas, D. H., 1973, An Empirical Test for Steward's Model of Great Basin Settlement Patterns. *American Antiquity* 38(1):155–176.

Thomas, D. H., 1981, God's Truth in Great Basin Archaeology? *American Antiquity* 46:644–648.

Thomas, D. H., 1982, An Overview of Central Great Basin Prehistory. In *Man and Environment in the Great Basin*, edited by D. B. Madsen and J. F. O'Connell, pp. 156–171. Paper No. 2, Society for American Archaeology, Washington, DC.

Thomas, D. H., 1983a, *The Archaeology of Monitor Valley 1:Epistemology*. Anthropological Papers 58, Part 1, American Museum of Natural History, New York.

Thomas, D. H., 1983b, *The Archaeology of Monitor Valley 2:Gatecliff Shelter*. Anthropological Papers 59, Part 1, American Museum of Natural History, New York.

Thomas, D. H., 1985, *The Archaeology of Hidden Cave, Nevada*. Anthropological Papers of the American Museum of Natural History 61, New York.

Thomas, D. H., 1988, *The Archaeology of Monitor Valley 3:Survey and Additional Excavations*. Anthropological Papers of the American Museum of Natural History 66, Part 2, New York.

Thomas, D. H., and Bettinger, R. L., 1976, *Prehistoric Piñon Ecotone Settlements of the Upper Reese River Valley, Central Nevada*. In Anthropological Papers, Vol. 53, Part 3. American Museum of Natural History, New York.

Thompson, R. S., and Hattori, E. M., 1983, Packrat (Neotoma) Middens from Gatecliff Shelter and Holocene Migrations of Woodland Plants. In *Archaeology of Monitor Valley:2. Gatecliff Shelter*, edited by D. H. Thomas, pp. 157–169. Anthropological Papers. Vol. 59. American Museum of Natural History, New York.

Wells, H. F., 1983, *Historic and Prehistoric Pinyon Exploitation in the Grass Valley Region, Central Nevada:A Case Study in Cultural Continuity and Change*, Ph.D. Dissertation, University of California, Riverside.

West, N. E., Tausch, R. J., Rea, K. H., and Tueller, P. T., 1978, Phytogeographical Variation Within Juniper-Pinyon Woodlands of the Great Basin. *Great Basin Naturalist* Memoirs 2:119–136.

West, N. E., Tausch, R. J., and Tueller, P. T., 1998, A Management-Oriented Classification of Pinyon-Juniper Woodlands of the Great Basin. General Technical Report 12, USDA Forest Service, Rocky Mountain Research Station, Ogden UT.

Wheat, M. M., 1967, *Survival Arts of the Primitive Paiutes*. University of Nevada-Reno, Reno.

Wigand, P. E., and Nowak, C., 1992, Dynamics of Northwestern Nevada Plant Communities During the Last 30,0000 Years. In *The History of Water:Eastern Sierra Nevada, Owens Valley, White-Inyo Mountains*, Vol. 4, edited by C. A. Hull, V. Doyle-Jones, and B, Widawski, pp. 40–62. White Mountain Research Station Symposium, University of California Press, Berkeley.

Zeanah, D. W., 1992, *A Transport Model of Optimal Pinyon Camp Location in the Great Basin*. Paper Presented at the 23rd Biennial Meeting of the Great Basin Anthropological Conference, Boise, ID.

Zeanah, D. W., 1996, *Predicting Settlement Patterns and Mobility Strategies:An Optimal Foraging Analysis of Hunter-Gatherer Use of Mountain, Desert, and Wetland Habitats in the Carson Desert*, Ph.D. Dissertation, University of Utah, Salt Lake City.

Zeanah, D. W., 2000, Transport Costs, Central-Place Foraging, and Hunter-Gatherer Alpine Land-Use Strategies. In *Intermountain Archaeology*, edited by D. B. Madsen and M. D. Metcalf, pp. 1–14. University of Utah Anthropological Papers No. 122, Salt Lake City.

Zeanah, D. W., and Simms, S. R., 1999, Modeling the Gastric: Great Basin Subsistence Studies Since 1982 and the Evolution of General Theory. In *Models for the Millennium:Great Basin Anthropology Today*, edited by C. Beck, pp. 118–114. University of Utah Press, Salt Lake City.